T-MATCHED DIPOLE TAG ANTENNA FOR UHF RFID APPLICATIONS

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ABSTRACT

Recently, Radio Frequency IDentification (RFID) systems have been rapidly developing in the Ultra High Frequency (UHF) band due to the different advantages offered in different fields.
The main goal of this paper is to present matched dipole tag antenna, fitting worldwide passive UHF RFID applications. The antenna is printed on an FR4 substrate with $\boldsymbol{\varepsilon_r = 4.7}$*; it has a size of* $\mathbf{139 \times 6.75 \times 1.635\ mm^3}$*. T-matched chart was also designed to match the antenna tag IC including a charge capacitor which compensates the large conductive reactance of the antenna impedance. Furthermore, the power from the antenna can be maximally delivered to a tag IC unless the antenna impedance is conjugately matched with that of tag IC. Simulation results demonstrate that the antenna has a suitable operating band from 759–947 MHz; it has nearly omnidirectional radiation patterns with proper gain.*

KEYWORDS: *Radio Frequency Identification (RFID), Dipole Tag Antenna, T-matching, Finite Integrate Technique (FIT), Method of Moment (MoM).*

I. INTRODUCTION

RFID (Radio Frequency IDentification) is an extremely important technology of automatic identification. It is being used in a wide range of applications such as Electronic Toll Collect (ETC), vehicle access, Electronic Article Surveillance (EAS), animal tagging, supply chain tracking, warehouse management, and security systems.
There are 4 common bands for RFID applications; these are the LF band (less than 135 KHz), the HF band (13.56 MHz), the UHF band (860 - 960 MHz), the microwave band (>2.45 GHz) and the Ultra Wide Band UWB (3.1-10.6 GHz) [1] [2].
RFID systems operating at UHF and Microwave frequencies have received considerable attention for various commercial applications, they can offer very fast reading and long read-range at the expense of the design complexity [3] [4], a great demand of passive UHF RFID system is expected to replace the current position of barcode system.
Basic RFID systems are mainly composed of two entities, namely reader and tag. Reader broadcasts queries to the tag in its wireless transmission range for information contained in tag, this last will reply with the required information.
In this paper, we present T-matched dipole tag antenna suitable for worldwide UHF RFID applications.
In reality, the design process is similar to the half-wave dipole antenna; however, it is so strong to get matching between the chip and the antenna because the trade-off between antenna-chip matching and resonance.
In fact, we seek to keep the small size antenna and to have a low real part (small resistance) and a

high positive imaginary part (high inductance) to get matching between the tag antenna impedance and the chip impedance.

In the current article, we focus the interest on designing a dipole antenna and matching its impedance to a specific chip's impedance. The paper is divided on two sections, the first one contains dipole antenna analysis and the chosen matched geometry, meanwhile the other treats the different results obtained by simulations tools, it is concluded by a conclusion in which, we present an overview of the paper and the perspectives for the near future.

II. ANTENNA DESIGN AND ANALYSIS

The slot T-match is a generalization of the folded slot dipole (as the wire T-match is a generalization of the folded wire dipole) and its behavior can be deduced either making a parallel with the wire case or directly applying Booker's formula, that relates input impedance of complementary planar structures in free space:

$$Z'_{in} = \frac{\eta^2}{Z_{in}}$$

Where η is the free space impedance. The slot T-match, indeed, is the complementary structure of the classic wire T-match. It is also related to the T-shaped coaxial feed for a cavity backed slot, which is a classic slot feeding system, well known for its wideband characteristics.

In RFID tags, the antenna's impedance has to be matched to their IC (Integrated Circuit); thus, the input impedance of the dipole of length l can be changed by introducing a centered short-circuited stub. The antenna source is connected to a second dipole of length $a \leq l$, placed at a close distance b from the first and larger ones (see Figure.1). It was proved in [5] that the impedance at the source point is given by:

$$Z_{in} = \frac{2Z_t(1+\alpha)^2 Z_A}{2Z_t + (1+\alpha)^2 Z_A} \quad (1)$$

Where $Z_t = jZ_0 \tan k_a/2$ is the input impedance of the short-circuit stub, $Z_0 \cong 276 \log_{10} b/\sqrt{r_e r'_e}$ is the characteristic impedance of the two-conductor transmission lines with spacing b, it is the dipole impedance taken at its center in the absence of the T-match connection; $r_e = 0.25w$ and $r'_e = 8.25$ are the equivalent radius of the dipole and of the matching stub and $a = \ln(b/r'_e)\,/\ln(b/r_e)$ is the current division factor between the two conductors.

The chip input impedance used in this layout at 915 MHz is Zc=28-j148 Ω which means the load antenna impedance should be Za=28+j148 Ω for maximum power transfer (conjugate matching).

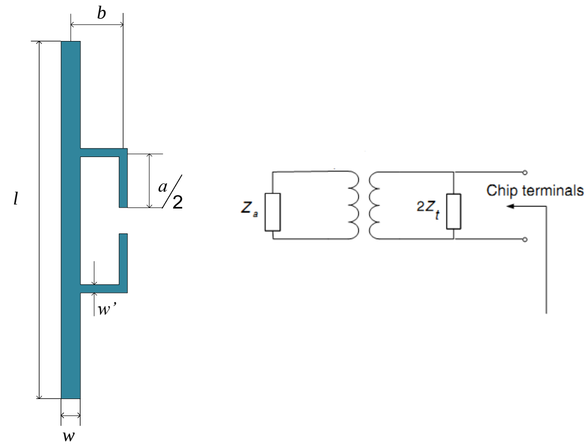

Figure 1. The T-match configuration for planar dipoles and its equivalent circuit

Figure. 2 shows the geometrical parameters of the Dipole tag antenna; a, b, and the trace's width, w and w' can be adjusted to match the complex chip impedance. Results have been obtained using

commercially available simulation softwares CST Microwave Studio [6], the obtained results was compared to those obtained by IE3D software [7].
The dipole was designed to achieve half-wavelength [8] ($\lambda/2$ ~16.4 cm at 915 MHz), however, its size was reduced by 15.24 % by inserting T-match.

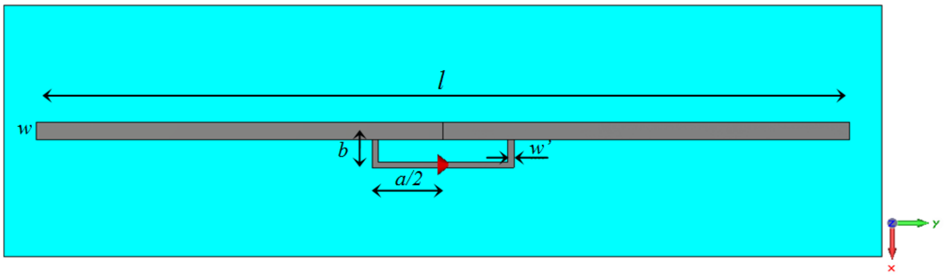

Figure 2. The T-match RFID antenna design layout

The antenna is made of PEC (Perfect Electronic Conductor) with a thickness of 0.035mm, we have used as a substrate the lossy FR-4 (εr=4.7 and loss tangent $\delta = 0.0019$) with a thickness of 1.6mm.
The designed antenna shown above has geometrical parameters of: l =139, a = 11, b = 4.75, w = 3 and w' = 1 the edges were chamfered to favorite the miniaturization.
These parameters were obtained after several simulations and parametrical studies.
If we compare the proposed design to those presented in [9]– [10], ours presents reduced size by 16.5% and 14.7% respectively, good matching on term of input impedance and S11. Inserting the stub helped to reduce its size, others miniaturisations techniques could be found on [13].

III. Simulation Results And Discussions

CST Microwave simulator [6], which is based on Finite Integral Technique (FIT) method, was used to optimize and analyze the antenna.
FIT analysis method is considered as one of the most successful numerical methods for the simulation of electromagnetic fields and of various coupled problems appeared 25 years ago [11]. The key idea behind the Finite Integration Technique (FIT) was to use, in the discretization, the integral, rather than the differential form of Maxwell's equations.
This early intuition proved to be correct and to possess numerous theoretical, algorithmic and numerical advantages, and was recently re-confirmed by the adoption of the exact same viewpoint in a historically completely different method, the finite element method (FEM) [12].
CST tool was used as a platform to design and to present antenna performances as return loss, gain, directivity, radiation pattern.
The results have been compared to those obtained by a second tool, this last works with the mixed-potential form of the integral equations (IE) formulation in the frequency domain. The metal parts as well as the dielectric substrates are modelled using surface integrals. The integral equations of the model are solved by Method of Moment (MoM) with the commercially available solver IE3D [7].
MoM method is the oldest method of deriving point estimators. It almost always produces some asymptotically unbiased estimators, although they may not be the best estimators.
Figure. 3 and Figure. 4 show the simulated real and imaginary parts of the antenna impedance behavior; we can notice that the dipole input impedance given by CST is 24.66+j148.07 Ω , while that obtained by IE3D is 28.00+j161.90 at 915 MHz, both of them are as close to the desired conjugate chip.

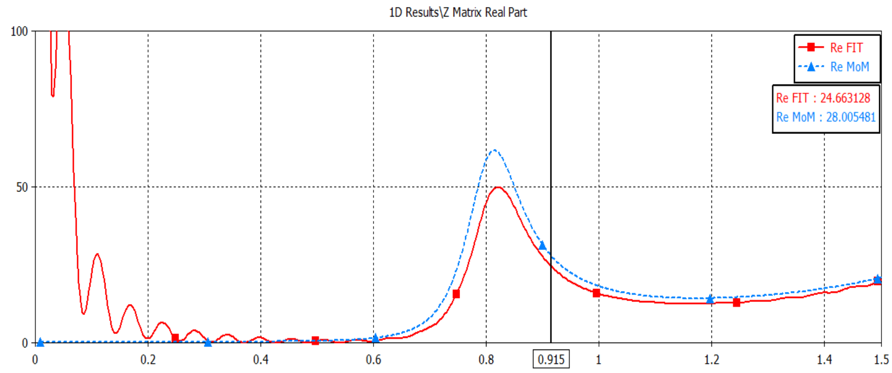

Figure 3. Comparison between the antenna impedance real parts obtained by CST and IE3D

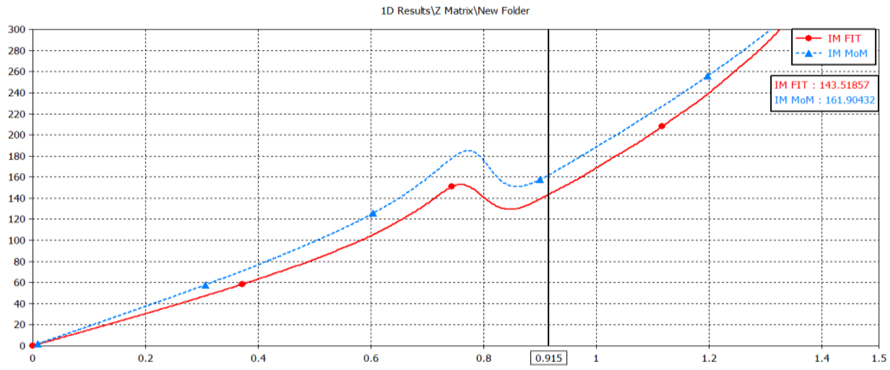

Figure 4. Comparison between the antenna impedance imaginary parts obtained by CST and IE3D

The high value of the Conjugate Match Factor (CMF) (Figure.5) (≅ 1) leads us to get a good impedance matching between the antenna and the chip.

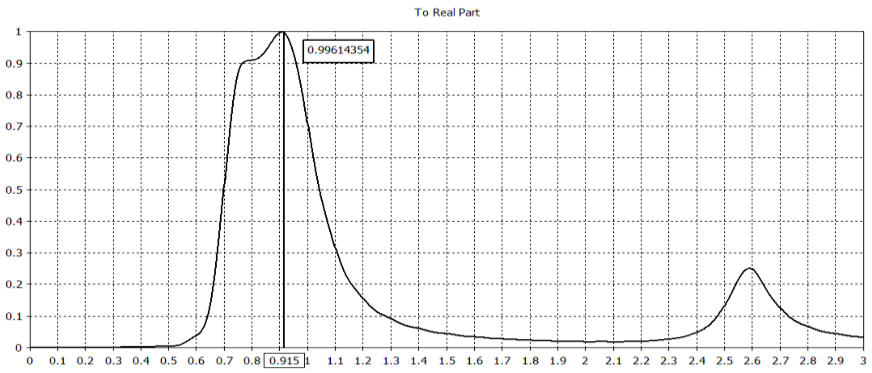

Figure 5. Conjugate Match Factor (CMF)

Figure 6 presents the return loss (S11) of the antenna obtained by the two softwares; at resonance (915 MHz), it is at -23.56 dB with (FIT), while it is -12.36 dB by (MOM). The observed deviation is due to the different numerical modeling and meshing techniques. Nevertheless, the variations are within tolerance, so we could say that both of the two models gave us a good estimation of the antenna performance.

The bandwidth of the antenna is up to 185 MHz where the |S11| is below -10 dB.

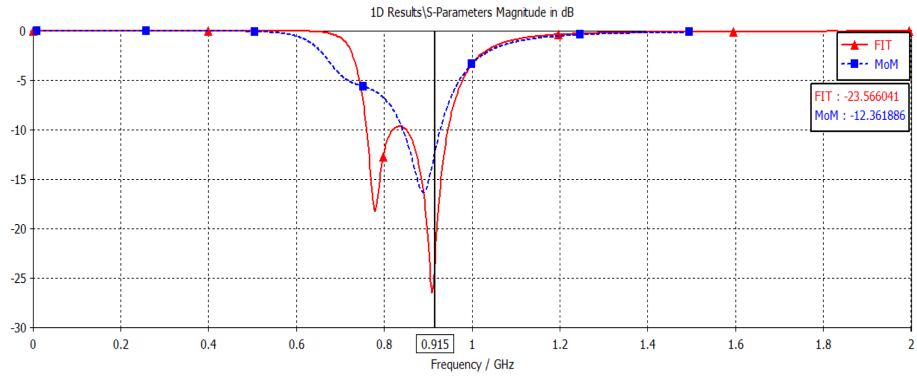

Figure 6: Return loss of the antenna S|11| (dB)

Figure 7 shows two radiation patterns of the proposed antenna at 915 MHz; it presents an almost omnidirectional (doughnut-shaped) radiation pattern. It is shown more properly in the 3D radiation pattern of polar gain (Figure.8); the diagram obtained is somewhat similar to the typical dipole with an omnidirectional radiation, the maximal gain of the antenna is of 2.27 dBi.

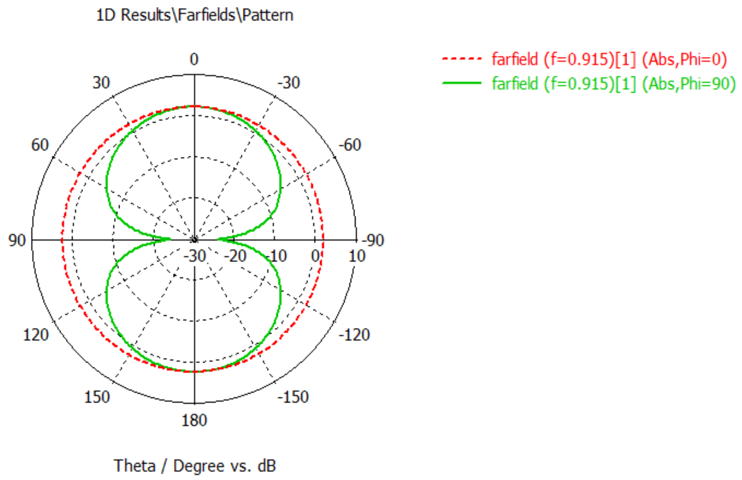

Figure 7. Simulated 2-D radiation pattern (Directivity pattern for phi=0 (x-z) and phi=90 (y-z) planes)

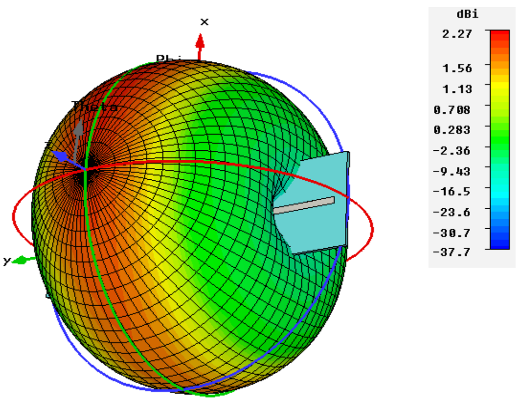

Figure 8. Simulated three dimensional radiation patterns

IV. CONCLUSION AND PERSPECTIVES

Radio frequency identification is a rapidly developing technology for automatic identification of objects. The proposed paper treated a dipole passive RFID tag antenna; it resonates on 915 MHz, frequency adequate to several RFID applications as vehicle localisations. We presented analysis design, and the dipole geometry, it has a good matching on term of S11on the desired frequency, with a bandwidth up to 185 MHz. The T-Matching was used to get good matching between the impedance of the antenna and the chip at the selected frequency; it was simulated with two different solvers. The proposed antenna size was reduced; it is cheap, flexible and suitable for UHF RFID universal application.

We have to continue our researches on the same axe; and improve our studies to get challenge of maximising read-range, impedance antenna matching with several industrial chips, and all this criteria's with keeping small size antenna, getting a prototype and validating it.

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